

INACTIVE AND ABANDONED MINE LANDS— Sierra Zinc Mine, Chewelah Mining District, Stevens County, Washington

by Fritz E. Wolff,
Donald T. McKay, Jr.,
and David K. Norman

WASHINGTON
DIVISION OF GEOLOGY
AND EARTH RESOURCES
Open File Report 2003-20
October 2003



WASHINGTON STATE DEPARTMENT OF
Natural Resources
Doug Sutherland - Commissioner of Public Lands

INACTIVE AND ABANDONED MINE LANDS— Sierra Zinc Mine, Chewelah Mining District, Stevens County, Washington

by Fritz E. Wolff,
Donald T. McKay, Jr.,
and David K. Norman

WASHINGTON
DIVISION OF GEOLOGY
AND EARTH RESOURCES
Open File Report 2003-20
October 2003



WASHINGTON STATE DEPARTMENT OF
Natural Resources
Doug Sutherland - Commissioner of Public Lands

DISCLAIMER

Neither the State of Washington, nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the State of Washington or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the State of Washington or any agency thereof.

WASHINGTON DEPARTMENT OF NATURAL RESOURCES

Doug Sutherland—*Commissioner of Public Lands*

DIVISION OF GEOLOGY AND EARTH RESOURCES

Ron Teissere—*State Geologist*

David K. Norman—*Assistant State Geologist*

Washington Department of Natural Resources
Division of Geology and Earth Resources
PO Box 47007
Olympia, WA 98504-7007
Phone: 360-902-1450
Fax: 360-902-1785
E-mail: geology@wadnr.gov
Website: <http://www.dnr.wa.gov/geology/>

Contents

Introduction	1
Summary	1
Ownership	1
Production history	2
Geologic setting.	3
Openings.	3
Materials and structures	3
Water	3
Milling operations	4
Waste-rock dumps and tailings	4
General information	4
Current ownership	5
Directions	5
Mine operations data	5
Physical attributes	5
Vegetation	6
Wildlife.	6
Water quality.	6
Acknowledgments	6
References cited	7
Appendix A: Methods and field equipment	8
Appendix B: Water quality standards for hardness dependent metals	9

FIGURES

Figure 1. Site map of the Sierra Zinc Mine in Stevens County	1
Figure 2. Photo showing main haulage tunnel, level 2 (lower) adit	2
Figure 3. Photo showing level 1 (upper) adit portal	2
Figure 4. Photo showing mill building complex	3
Figure 5. Photo showing north side of the mill	4
Figure 6. Photo showing containers of flotation reagents and lubricants stored in the old mill building	4
Figure 7. Photo showing mill tailings	5
Figure 8. Photo showing dark gray tailings overlying light gray tailings	6
Figure 9. Photo showing dark gray tailings in the northwest corner of the tailings dump	7

TABLES

Table 1. Mine features	5
Table 2. Soil analysis	6
Table 3. Model Toxics Cleanup Act	6
Table 4. Bat information	6
Table 5. Surface water field data	6
Table 6. Surface water analysis.	7

Inactive and Abandoned Mine Lands— Sierra Zinc Mine, Chewelah Mining District, Stevens County, Washington

Fritz E. Wolff, Donald T. McKay, Jr., David K. Norman
Washington Division of Geology and Earth Resources
PO 47007; Olympia, WA 98504-7007

INTRODUCTION

Presently in Washington State there is no systematic database of inactive and abandoned metal mines (Norman, 2000). Previous work by the Department of Natural Resources (DNR) has had a distinctly commodity-oriented focus (Hunting, 1956; Derkey and others, 1990). The current goal is to build a single database and geographic information system (GIS) coverage of major mines in the state. Documentation will focus on physical characteristics and hazards (openings, structures, materials, and waste) and water-related issues (acid mine drainage and/or metals transport). Accurate location, current ownership, and land status information will be included. Acquisition of this information is a critical first step in any systematic approach to determine if remedial or reclamation activities are warranted. Open-File Reports (OFRs) will provide written documentation on mines or groups of mines within specific mining districts or counties.

Over 3800 mineral properties have been located in the state during the last 100 years (Hunting, 1956). Many are undeveloped prospects of little economic importance. Therefore, in considering the population to include in the Inactive and Abandoned Mine Land (IAML) inventory, we have identified approximately 60 sites that meet one of the following criteria: (a) more than 2000 feet of underground development, (b) more than 10,000 tons of production, (c) location of a known mill site or smelter. This subset of sites includes only metal mines no longer in operation.

We have chosen to use the term *inactive* in the project's title in addition to the term *abandoned* because it more precisely describes the land-use situation regarding mining and avoids any political or legal implications of surrendering an interest to a property that may re-open with changes in economics, technology, or commodity importance.

Creation of the state-managed IAML database is a cooperative effort between DNR, the U.S. Forest Service (USFS), the U.S. Bureau of Land Management (BLM), the U.S. Environmental Protection Agency (EPA), and the Washington Department of Ecology (DOE). DNR's Division of Geology and Earth Resources (DGER) is the lead

agency. To date, USFS contracts have been the principal source of funding, with other contributions coming from DNR and EPA.

SUMMARY

The Sierra Zinc mine, also known as the Aladdin or Blue Ridge mine, is located about 20 miles northeast of the Colville Municipal Airport on the west side of Aladdin Road. The property is less than one-fourth mile upland from north fork of Deep Creek. The mill remains and tailings are visible from the highway. The mine and tailings lie in sec. 20, T38N R41E (Fig. 1).

Ownership

All the lands formerly mined lie 1 mile west of the Colville National Forest. The BLM controls the subsection of land containing the main haulage tunnel and the underground workings.

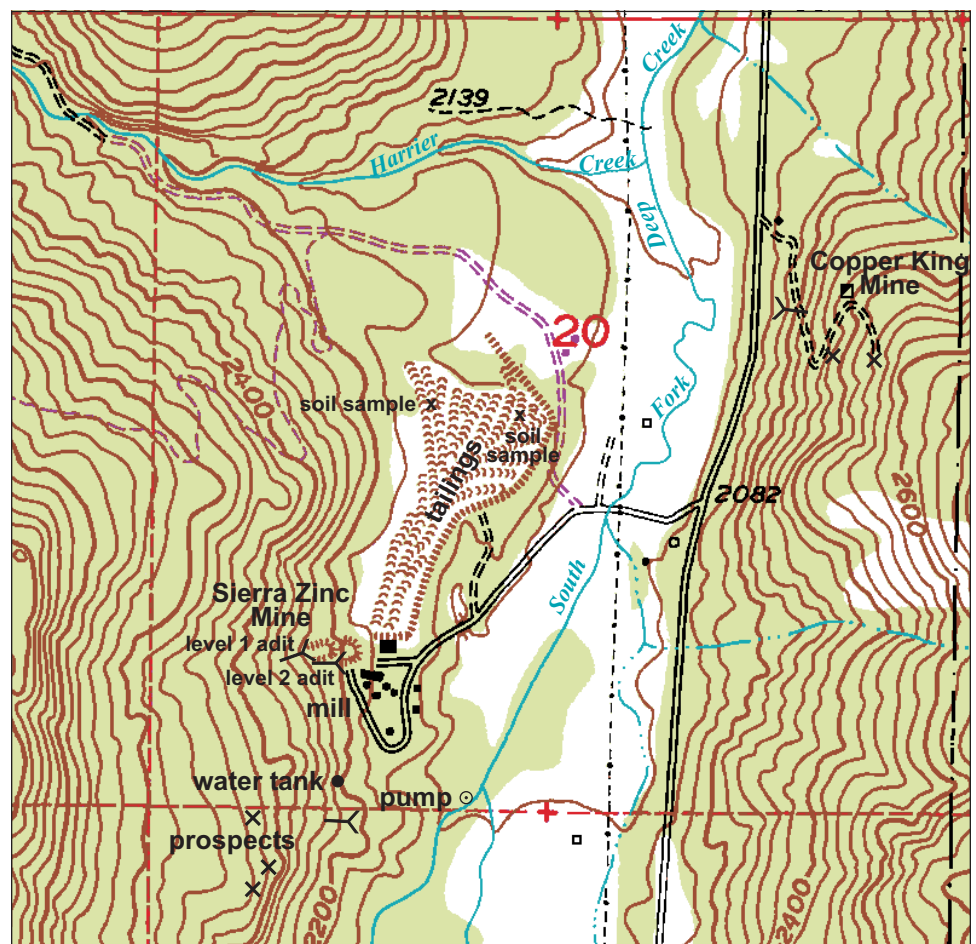


Figure 1. Site map of the Sierra Zinc mine in Stevens County. Section lines are 1 mile apart.

Private parties own contiguous tax parcels where the mill and all of the mill tailings, which cover an area of approximately 25 acres, are located. Sierra Zinc Co. formerly owned 230 acres of patented homestead ground and 130 acres of deeded land in addition to staked ground. (DGER mine file). None of the mining claims were ever patented, and no unpatented claims were on active status in February 2003 (BLM LR2000 database). DGER personnel performed field work at the site on Sept. 12, 2001 and again on June 13, 2002.

Production History

According to Mills (1977), the first claim was staked in 1889. A small tonnage of ore was mined and shipped between 1906 and 1910 by the Aladdin Mining Co. Although the Blue Ridge Mining Co. produced a few carloads of ore in 1926, the principal development of the property took place during the period from 1941 to 1944 under the direction of the Sierra Zinc Co. Sierra constructed a 90 tons/day flotation mill, expanded the mine openings, and produced a total of 56,000 tons. The mine lay idle from 1944 until 1949 when Goldfield Consolidated Mining Co. reopened the haulage tunnel (level 2 adit), the lower stopes, and increased the mill capacity to 500 tons/day. However, it appears Goldfield's primary interest centered on the mill's availability. The 713,000 tons mined during this period from Goldfield's operation at the nearby Deep Creek mine all went through the Sierra Zinc mill. Goldfield's only reported production from the Sierra Zinc property, 1380 tons, took place during 1956 (Fulkerson and Kingston, 1958). We believe Truman C. Higginbotham, mining engineer and former superintendent of the mine, maintained possessory title of the property for some time after Goldfield ceased operations. Goldfield deregistered as a corporation with the State of Washington in 1969. Coronado Development Co. obtained a lease from Higginbotham in September of 1972 (DGER mine file). That company performed surface exploration on one of the claims by bulldozer trenching, which uncovered a small amount of mineralized float. Nothing further is known about work done by the lessee. Tri-Nite Mining Co. acquired the mine and mill circa 1976. The last entry in the DGER mine files is an affidavit of assessment work performed by Chevron Resources, Inc., in 1981 under an exploration lease agreement with Tri-Nite Mining Co. Chevron Resources performed detailed geologic mapping and geochemical soil sampling on 12 claims and subsequently dropped the agreement.



Figure 2. Main haulage tunnel, level 2 (lower) adit. Note standing water on floor.



Figure 3. Level 1 (upper) adit.

Tri-Nite Mining Co. changed their corporate entity to the American Trading and Exchange Corporation (American) in 1984. Bureau of Land Management (BLM) records indicate that American sold the claims to an entity known as Brush Prairie, Inc., in 1988. Brush Prairie maintained the claims on active status through annual assessment work or maintenance fees until 1993, at which time BLM was unable to contact the registered agent and the claims were judged abandoned (BLM LR2000 database).

Geologic Setting

The Sierra Zinc orebody, like many other lead-zinc deposits in Stevens County, occurs in metasediments surrounding the margin of the granitic Spirit Pluton. The main workings in the mine were concentrated in intensely folded quartzite, schist and calcitic marble that has been intruded by igneous sills, dikes, and irregular masses of granite and dacite. Extensive metamorphism and faulting have complicated all attempts to correlate the mine rocks with host rocks at other mines in the area. In response to this problem, Yates (1964) referred to the host rocks as the Blue Ridge Sequence.

The principal ore host is calcitic marble, which attains a maximum thickness of 44 feet along the main haulage level. A prominent post-ore low-angle fault following the contact between granodiorite and marble appears to have been a major factor in localizing sulfide mineralization. It strikes predominantly northeast and dips northwest approximately 20 degrees. This fault zone was followed by a winze from the surface down dip approximately 200 feet. The average run of mine ore contained 6.5 percent zinc, 1 percent lead, 10 percent iron, and less than 1 ounce of silver per ton. The best exposures of ore contained sphalerite with pyrite in conformable parallel bands or beds up to several centimeters in thickness. Locally abundant galena was encountered in widely separated lenses within or near the fault described above, however the mine's overwhelming metallic value was in zinc (Campbell, 1946).

The Sierra Zinc ore deposit has a distinctly “now you see it, now you don't” quality that seriously affected production and development plans by previous operators. In an effort to apply rigorous geotechnical investigation to the problem and to extend ore reserves during World War II, the U.S. Bureau of Mines initiated a mapping and diamond-drilling program under the direction of Charles D. Campbell. The holes were planned to intersect projections of known ore exposed in the mine in old workings north and south of the main adit. Six holes were drilled totaling 1587 lineal feet. Mineralization was encountered in only one hole. It consisted of a 2-foot intercept containing 11 percent zinc and 1 percent lead 200 feet north of the present workings, at an intercept elevation of 2100 feet (Campbell, 1946). Campbell attempted to correlate various structural features with the presence of ore lenses. He concluded however, that “...no correlation was evident. Conflicting evidence is the rule. Either some unsuspected control of ore deposition was operative, or the controlling pre-mineral structure has been obscured by the process of ore deposition or later tilting.” In 1971, Mills (1977) examined an area 1000 feet south of the mill near an abandoned tunnel and found an exposure with parallel banding of galena, sphalerite and pyrite in calcitic marble.

Openings

Campbell (1946) puts the total development of the Sierra Zinc mine at approximately 4935 feet, consisting of six adits, four production levels, and several stopes. A 260-foot, 30-degree inclined shaft connected levels 1 and 2 underground. The two



Figure 4. Mill building complex. View to the northwest.

adits drive horizontally almost due west into a low-lying ridge. Both openings intersected ore-bearing marble at a point 400 feet from the respective portals. Winzes follow the ore down dip from those intersections to levels 3 and 4. Campbell (1946) reported that stopes above the main haulage tunnel (level 2 adit) collapsed in 1945. DGER personnel located the haulage tunnel above a dump several hundred feet west of the mill. The portal was open but deteriorating, with 12 inches of water standing behind slough for an unknown distance (Fig. 2). According to a local resident, this opening was plugged for some time by a cave-in at the portal. In the spring of 1999, impounded water apparently shot across the dump, rolling 3-foot diameter boulders in the flow, which dissipated in energy and volume as it ran toward the mill (Ron Nixon, oral commun., 2002). Another adit (level 1) is located 100 feet higher than the level 2 adit and slightly to the north. The portal is open, but the cross section is caved about 20 feet inside. The original timber supports are soft and deteriorating (Fig. 3).

Materials and Structures

The mill is a wood multi-tiered structure. Most of the original machinery was moved to the Schumaker mine in the 1960s. Areas with galvanized roofing still in place remain relatively stable (Fig. 4), however, other parts of the mill are deteriorating because various structural members have been taken for other uses (Fig. 5). The building should be considered hazardous. DGER personnel found six 55-gallon drums of miscellaneous petroleum products (labels unreadable), one drum of Aero 633 Depressant, and two drums of methyl isobutyl carbonic alcohol, also marked methyl amyl alcohol (Fig. 6). Private parties occupy several buildings constructed during previous mining activity.

Water

We observed a 5-gallons/minute discharge from the level 2 adit that infiltrated the dump 50 feet from the portal. Drainage from internal workings had formed a pool approximately 12 inches

deep that extended inside the tunnel an unknown distance. A sample taken in September of 2001 had a conductivity of $970\ \mu\text{S}/\text{cm}$ and a pH of 7.0. A sample taken in June of 2002 had a conductivity of $530\ \mu\text{S}/\text{cm}$ and a pH of 5.7. Concentrations of the metals analyzed (As, Cd, Cu, Fe, Pb, Zn) indicate that the mine discharge meets the metals requirement for human consumption. The zinc content in one sample was slightly above the requirement for chronic affect to aquatic life (see Table 6).

Milling Operations

Sierra Zinc Co. constructed the mill in 1941 at the inception of mining. Its original capacity was 90 tons/day, using crushing, ball-mill grinding, and flotation technology. Goldfield Consolidated increased the capacity to 500 tons/day. For a complete description of the mill's equipment and flow sheet, see *Mining World* (1943).

Waste-Rock Dumps and Tailings

The major waste-rock dump in terms of volume is located adjacent to the portal of level 2. It contains an estimated 50,000 tons of unmineralized quartzite, schist, and marble. The tailings impoundment stretches northerly from the mine approximately one-half mile and spreads out to about 530 feet in width (Fig. 7). The total area measured from aerial photographs is 25 acres. The tailings closest to the mill are 12 to 15 feet high, tapering off to the north where the thickness is estimated at 2 to 3 feet. Most of the material is very light gray in color. However, a layer of distinct black tailings lying conformably on the lighter material was observed at the northwest corner (Figs. 8 and 9). Samples of both materials exceeded levels for lead, zinc and cadmium listed in Model Toxics Control Act for unrestricted land use (see Tables 3 and 4).

GENERAL INFORMATION

Names: Sierra Zinc, also Aladdin and Blue Ridge

MAS/MILS sequence number: 0530650433

Access: two-wheel-drive road to mill site and level 2 adit

Status of mining activity: none

Claim status: Per the Mining Law of 1872, lode mining claims fall in two categories:

1. *Unpatented claims* require a minimum annual expenditure of \$100 assessment work per claim. A \$100 maintenance fee may be paid in lieu of performing assessment work. Unpatented claims are classified as *active* or *closed*. *Active* de-



Figure 5. North side of the mill. View to the west.



Figure 6. Containers of flotation reagents and lubricants stored in the old mill building.

notes a valid, up-to-date claim. *Closed* denotes that the maintenance fee, assessment work, or other requirements have not been met, and that the claim is no longer valid. The following table contains information on active claims only.

2. *Patented claims* are owned in fee simple by the discoverer and their assigns. A mineral survey is performed as part of the patent application process, prior to the issuance of a patent. Some lode claims initially mined underground may at a later date turn into an open pit operation. If this occurs, a

Surface Mining Permit is required, which contains certain stipulations regarding reclamation.

Current Ownership

BLM administers the land containing the mine openings and waste-rock dump. Information on ownership of the mill, tailings area, and contiguous parcels may be obtained from the Stevens County Assessor's Office, Colville, WA.

Location and map information:

Mine name	County	Location	Decimal longitude	Decimal latitude	1:24,000 quad	1:100,000 quad
Sierra Zinc	Stevens	sec. 20, T38N R41E	117.66784	48.77431	Spirit	Colville

Directions

Follow Aladdin Road north from the Colville Airport to a wye at two miles. Turn right and continue north approximately 18 miles. Look for a sign on the west side of the highway "Blue Ridge Mine Road". The mine and tailings are located 0.5 mile from the highway. Several residences situated around the mill and tailings area are on private land holdings. Check with local residents before proceeding.

Mine Operations Data

Type of mine: underground

Commodities mined: zinc, with minor lead and silver values

Geologic setting: Intensely folded quartzite, schists, and calcitic marble (Mills, 1977). Yates (1964) tentatively interpreted these rocks as Precambrian in age.

Ore minerals: sphalerite, [argentiferous] galena, chalcopryrite, molybdenite and smithsonite (Derkey, 1990)

Non-ore minerals: pyrite (FeS_2) and quartz veins carrying minor sulfides

Period of production: 112 tons in 1926, 56,100 tons in the period 1941–1944, 1380 tons in 1956 (Fulkerson and Kingston, 1958)

Development: Two adits totaling 4935 feet and a 470-foot inclined shaft. Principal working are on four levels. Upper two levels are connected to the lower two by a 260-foot, 30-degree winze (Campbell, 1946).

Production: approximately 57,380 tons of ore yielding 5,703,239 pounds of zinc, 889,937 pounds of lead, 57,143 pounds of copper, 29,058 ounces of silver, and 754 ounces of gold

Mill data: flotation technology, separate lead and zinc circuits, primary and secondary crushing, ball-mill grinding, and classifier sizing

PHYSICAL ATTRIBUTES

Features: see Table 1

Materials: two 50-gallon drums of methyl isobutyl carbonic (methyl amyl alcohol), one 50-gallon drum of Aero 633 Depressant, two 50-gallon drums of miscellaneous lubricants

Machinery: No mining machinery remains on the property. Tri-Nite Mining Co. may have moved some of the Sierra milling equipment to the nearby Schumaker mine circa 1974. Whether this move actually took place or not is a matter of conjecture; but as it stands, no ball mills, flotation cells, or other equipment remain at the Sierra millsite.

Structures: The mill is badly deteriorated structurally. It appears that the mine office, bunkhouse, and cookhouse described in the *Mining World* (1943) article as part of the mining operation have been converted to residential use.

Waste-rock dumps, tailings, impoundments, highwalls, or pit walls: The waste-rock dump adjacent to the main haulage tunnel (level 2 adit) is 3- to 12-inch unmineralized shot rock. The tailings impoundment covers an area of 25 acres north of the mill and is approximately 2500 feet long by 530 feet wide. It



Figure 7. Mill tailings, approximately 0.5 miles in length. View to the north.

Table 1. Mine features. **, data from DGER mine file

Description	Condition	Fenced (yes/no)	Length (feet)	Width (feet)	Height/depth (feet)	True bearing	Elev. (feet)	Decimal longitude	Decimal latitude
level 2 (lower) adit	open; slough around portal; standing water 12-inches deep on floor	no	1785 including crosscuts**	6	8	N85W	2340	117.66784	48.77431
level 1 (upper) adit	slough covers all but ~18 inches of clearance below portal timbers; closed 20 feet inside entrance	no	400**	5	7	S75W	2440	117.6688	48.77446

has a thickness of 12 to 15 feet near the mill and thins out to some unknown thickness at the northwest corner, estimated at 3 feet. As explained above, the tailings volume is considerably disproportionate to the amount of tonnage mined solely at the Sierra Zinc mine. Assuming from historical records that most of the 763,000 tons mined by Goldfield at the Deep Creek mine were processed through the Sierra mill, and adding 56,000 tons reported production from Sierra, a total of 819,000 tons were milled at the site (DGER mine file). With a mill recovery rate of 0.88 percent (Campbell, 1946), a material balance calculation puts the present tailings volume in the range of 500,000 to 606,000 cubic yards. The calculated average thickness is between 4 feet and 5 feet.

Analysis of tailings and dumps: see Tables 2 and 3

Waste rock, tailings, or dumps in excess of 500 cubic yards: yes

Reclamation activity: none

VEGETATION

The tailings are devoid of vegetation. The area around the level 2 portal supports a stand of inland forest species (fir, pine, and larch) with willow, various mosses and ocean spray wildflowers.

WILDLIFE

None observed. See Table 4.

WATER QUALITY

Surface waters observed:

Deep Creek

Proximity to surface waters:

one-half mile

Domestic use: livestock.

Acid mine drainage or staining: none.

Surface water field data: see Table 5

Surface water sample analysis: see Table 6

Surface water migration: Water discharging from the haulage tunnel (level 2 adit) infiltrates 50 feet from the portal.

ACKNOWLEDGMENTS

The authors thank editor Jari Roloff for helpful suggestions on the layout and content of this report. Washington State Archives personnel helped document periods of operation by various mining concerns. Thanks to the U.S. Forest Service, Region 6, and particularly Bob Fujimoto and Dick Sawaya, for funding this work.



Figure 8. Dark gray tailings overlying light gray tailings. Eight-inch notebook for scale.

Table 2. Soil analysis. Metal concentrations are milligrams per kilogram. Numbers in parentheses indicate the factor by which the analysis exceeds standards shown in Table 3. ---, no data

Sample location	Arsenic	Cadmium	Copper	Iron	Lead	Mercury	Zinc	Gold
northeast corner of tailings; light gray material	10.6	21.1	33.6	12,400	1270 (6X)	---	4510 (17X)	---
northwest corner of tailings; dark gray material	11.4	81.2 (3.2X)	99.2	20,800	2120 (10X)	---	16,400 (61X)	---

Table 3. Model Toxics Cleanup Act, WAC 173-340-900. Table 749-2. Priority contaminants of ecological concern for sites that qualify for the simplified terrestrial ecological evaluation procedure (partial data). Concentrations are in milligrams per kilogram. Levels shown are for unrestricted land use. Levels for silver, gold, and iron are not specified

Metals	Arsenic III	Cadmium	Copper	Lead	Mercury	Zinc
Level, mg/kg	20	25	100	220	9	270

Table 4. Bat information

Opening	Aspect	Air temp. (°F) at portal	Air flow: exhaust	Air flow: intake	Multiple openings	Bats or bat evidence
level 1 adit	NE	53	no	yes	yes	no

Table 5. Surface water field data

Description	Flow (gpm)	Conductivity (µS/cm)	pH	Bed color	Temp (°F)	Elev. (feet)
discharge from level 2 haulage tunnel	5	970 (Sept. 2001) 530 (June 2002)	7.0	natural	45	2340

Table 6. Surface water analysis. Metal concentrations are micrograms per liter; hardness is in milligrams per liter. ---, no data; **, standards for these metals are hardness dependent. Conversion formulae are shown in <http://www.ecy.wa.gov/pubs/wac173201a.pdf>. Standards calculated for hardness values specific to Part 1 below, are shown in Appendix B

PART 1: ANALYSIS BY USEPA METHOD 6020, INDUCTIVELY COUPLED PLASMA/MASS SPECTROMETRY*

Sample location	Arsenic	Cadmium	Copper	Iron	Lead	Mercury	Zinc	Hardness
level 2 haulage tunnel discharge Sept. 2001	---	<5	---	---	<10	---	500	500
level 2 haulage tunnel discharge June 2002	<10	<5	<10	<100	12.3	---	296	500

PART 2: APPLICABLE WASHINGTON STATE WATER QUALITY STANDARDS

Type of standards (applicable Washington Administrative Code)	Arsenic	Cadmium	Copper	Iron	Lead	Mercury	Zinc	Hardness
Surface water standards (WAC 173-201A, Standard for aquatic life in surface freshwater, chronic level maximums at 100 mg/L hardness)	190	**	**	none	**	0.012	**	100
Ground water standards (WAC 246-290, Washington State Department of Health, standards for ground water, domestic consumption)	50.0	none	1300	300 (cosmetic only)	15	2.0	5000	---

REFERENCES CITED

- Campbell, C. D., 1946, Geology and ore deposits of the Sierra zinc area, Colville district, Stevens County: U.S. Geological Survey Open-File Report, 51 p., 10 plates.
- Derkey, R.E.; Joseph, N.L.; Lasmanis, Raymond, 1990, Metal mines of Washington—Preliminary report: Washington Division of Geology and Earth Resources Open File Report 90-18, 577 p.
- Fulkerson, F. B.; Kingston, G. A., 1958, Mine production of gold, silver, copper, lead, and zinc in Pend Oreille and Stevens Counties, Wash., 1902–56; Annual totals by mines, districts, and counties: U.S. Bureau of Mines Information Circular 7872, 51 p.
- Hunting, M. T., 1956, Inventory of Washington minerals; Part II—Metallic minerals: Washington Division of Mines and Geology Bulletin 37, Part II, 2 v.
- Mills, J. W., 1977, Zinc and lead ore deposits in carbonate rocks, Stevens County, Washington: Washington Division of Geology and Earth Resources Bulletin 70, 171 p.
- Mining World, 1943, Sierra Zinc Company—Unpretentious Washington property produces important war metal: Mining World, v. 5, no. 3, p. 22, 24-25, 27-28.
- Norman, D. K., 2000, Washington's inactive and abandoned metal mine inventory and database: Washington Geology, v. 28, no. 1/2, p. 16-18.
- Yates, R. G., 1964, Geologic map and sections of the Deep Creek area, Stevens and Pend Oreille Counties, Washington: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-412, 1 sheet, scale 1:31,680. ■



Figure 9. Dark gray tailings in the northwest corner of the tailings dump. View to the south.

Appendix A

METHODS

We recorded observations and measurements in the field. Longitude and latitude were recorded in NAD83 decimal degree format. Literature research provided data on underground development, which was verified in the field when possible.

All water samples were collected as simple grab samples in pre-cleaned 500 mL HDPE bottles with preservative and kept on ice for transport to Sound Analytical Services, Inc. (SAS). Soil samples from dumps or tailings were taken from subsurface material and double bagged in polyethylene. Chain of custody was maintained.

Water and soil samples were analyzed for arsenic, cadmium, copper, iron, lead, and zinc by inductively coupled plasma/mass spectrometry (ICP/MS) following USEPA Method 6010. Samples were analyzed for mercury by cold vapor atomic absorption (CVAA), USEPA Method 7470 (water), and Method 7471 (soil).

Holding times for the metals of interest were observed (28 days for mercury, 180 days for other metals). Instrument calibration was performed before each analytical run and checked by standards and blanks. Matrix spike and matrix spike duplicates were performed with each set.

FIELD EQUIPMENT

barometric altimeter
binoculars
digital camera
flashlight
Garmin GPS III+, handheld GPS unit
Hanna Instruments DiST WP-3 digital conductivity meter
and calibration solution
litmus paper, range 0–14, and 4–7
Oakton digital pH meter
Oakton digital electrical conductivity meter
Taylor model 9841 digital thermometer

Appendix B

WATER QUALITY STANDARDS FOR HARDNESS DEPENDENT METALS

WAC 173-201A. Chronic standard ($\mu\text{g/l}$). ---, no data

Sample location	Hardness (mg/l)	Cd ($\mu\text{g/l}$)	Cu ($\mu\text{g/l}$)	Pb ($\mu\text{g/l}$)	Zn ($\mu\text{g/l}$)
Sierra Zinc level 2 adit	500	3.4	45	13.7	409